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DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150559

SITE SELECTION FEASIBILITY ANALYSIS FOR A SOLAR ENERGY SYSTEM ON THE FAIRBANKS FEDERAL BUILDING

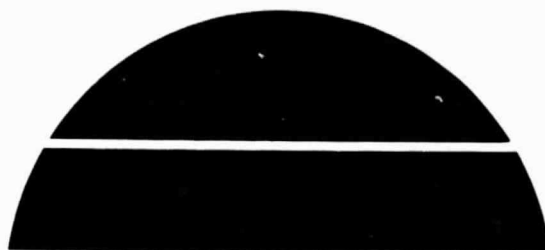
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For the U. S. Department of Energy



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FOR A SOLAR ENERGY SYSTEM ON THE FAIRBANKS
FEDERAL BUILDING (IBM Federal Systems Div.)
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Solar Energy

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16. ABSTRACT A feasibility study has been performed for the installation of a solar energy system on the Federal Building in Fairbanks, Alaska, a multi-floor office building with an enclosed parking garage. The study consisted of determining the collectable solar energy at the Fairbanks site on a monthly basis and comparing this to the monthly building heating load. Potential conventional fuel savings were calculated on a monthly basis and the overall economics of the solar system applications were considered. Possible solar system design considerations, collector and other system installation details, interface of the solar system with the conventional HVAC systems, and possible control modes were all addressed. Conclusions, recommendations and study details are presented.			
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TABLE OF CONTENTS

INTRODUCTION	1
CONCLUSIONS	2
CLIMATOLOGICAL FACTORS	3
BUILDING HEATING REQUIREMENTS	7
SOLAR ENERGY SYSTEM DESIGN & PERFORMANCE FACTORS	12
ECONOMIC CONSIDERATIONS	34
SOLAR AND CONVENTIONAL HEATING SYSTEM INTERFACE	37
SOLAR SYSTEM INSTALLATION	41

INTRODUCTION

In response to a MSFC Technical Directive (Number 20) under the SIMS Program, a feasibility study was performed for the installation of a solar energy system on the Fairbanks, Alaska, Federal Building.

This is a multi-floor office building with an enclosed parking garage. Located nearby is a motor pool shop. The main building has four-floor office wings along the north and east sides and a three-floor parking garage within the southwest corner.

HVAC requirements are currently met by an oil fired boiler, a heat recovery system comprised of air conditioning and heat pump units, and ventilation and supply fans. Main building heat is also supplied to the detached motor pool shop.

The study consisted of determining the collectable solar energy at the Fairbanks site on a monthly basis and comparing this to the monthly building heating load. Potential conventional fuel savings were calculated on a monthly basis and the overall economics of the solar system applications were considered. Possible solar system design considerations, collector and other system installation details, interface of the solar system with the conventional HVAC systems, and possible control modes were all addressed. Conclusions, recommendations and study details are presented in following sections of this report.

CONCLUSIONS

The following conclusions resulted from this feasibility study:

- o A solar system can be physically installed at the Fairbanks site, although the collector array will have to be ground mounted.
- o Conventional yearly fuel savings up to 19.3%, corresponding to 8,000 gallons of fuel oil, are possible with installation of the conceived solar system, assuming 4,000 ft² of effective collector area.
- o Although the first-cut calculations contained in this report indicates that some economic savings over a 20-year period are feasible, uncertainties associated with purchase and installation costs (which are expensive in the Fairbanks area) of a final system design and with projected fuel oil costs over this period make an economic conclusion unrealistic from a study of this brevity. In fact, an overall economic loss is quite possible.

Overall, whether a solar energy system is deemed feasible for the Fairbanks site will depend upon the importance of each of the three listed conclusions to the user.

CLIMATOLOGICAL FACTORS

Fairbanks is located in the interior of Alaska at latitude 64.8°N and longitude 147.9°W . The surrounding mountain ranges toward the south are approximately one degree above true horizon. During the months of June and July the sun is above the horizon from 18 to 21 hours each day. Conversely, during December and January, the sun is above the horizon only 3 to 6 hours each day. A sun path diagram for Fairbanks is provided as Figure 1. Amounts of cloudiness are low, on the average, the year around. The period from January through April is particularly clear.

Figure 2 presents the available solar energy on the horizontal, as well as on tilted surfaces of 60, 75 and 90 degrees. Wintertime insolation values are quite low because of the short period of sunlight at that time of year. It can be seen that available solar energy peaks in March. The latter months of the year are significantly degraded by cloudiness and precipitation.

Table 1 presents a monthly summary of climatic conditions associated with the collection of solar energy.

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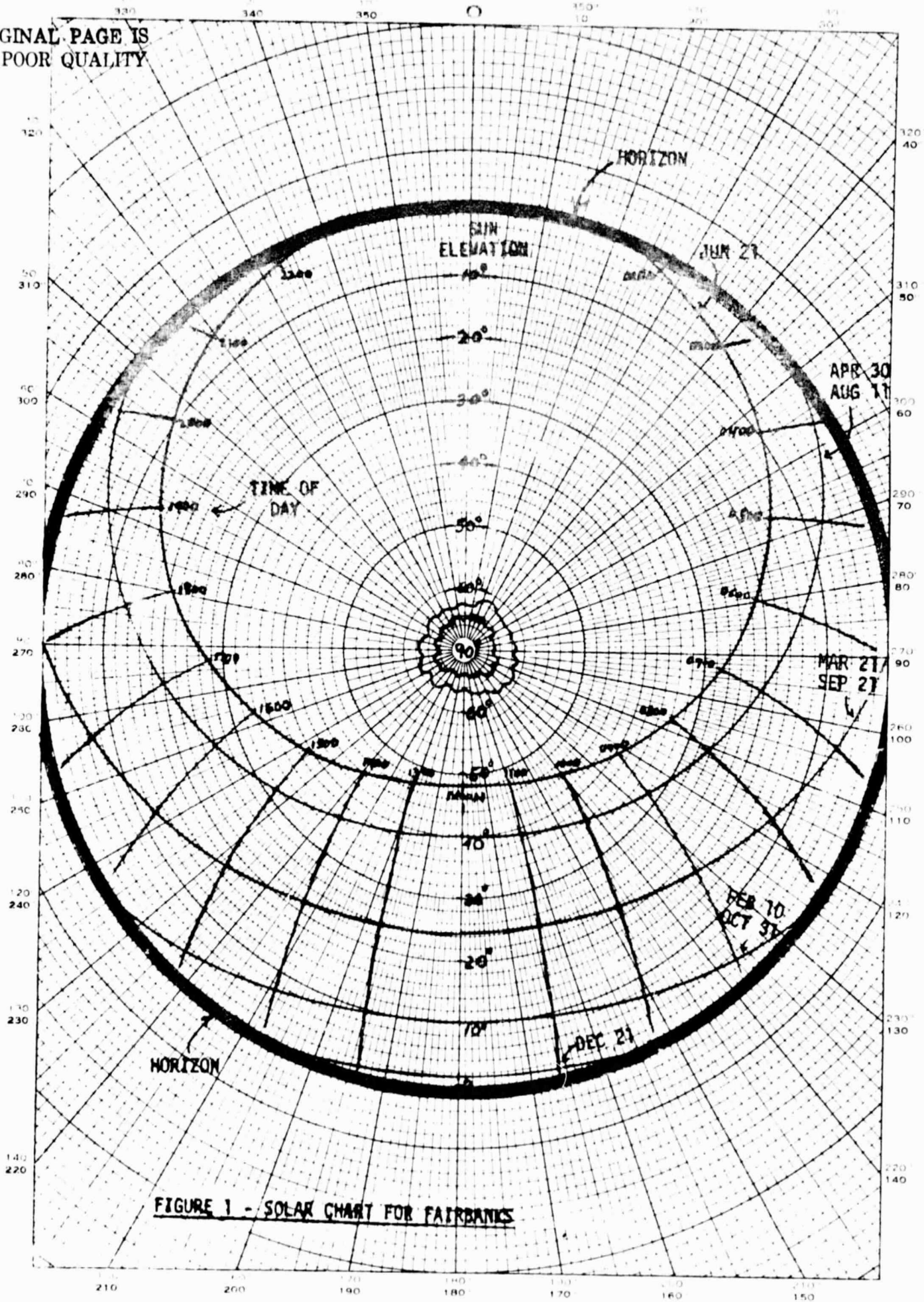


FIGURE 1 - SOLAR CHART FOR FAIRBANKS

AVAILABLE SOLAR ON A TILTED SURFACE
(103 BTU per Sq. Ft. per Month)

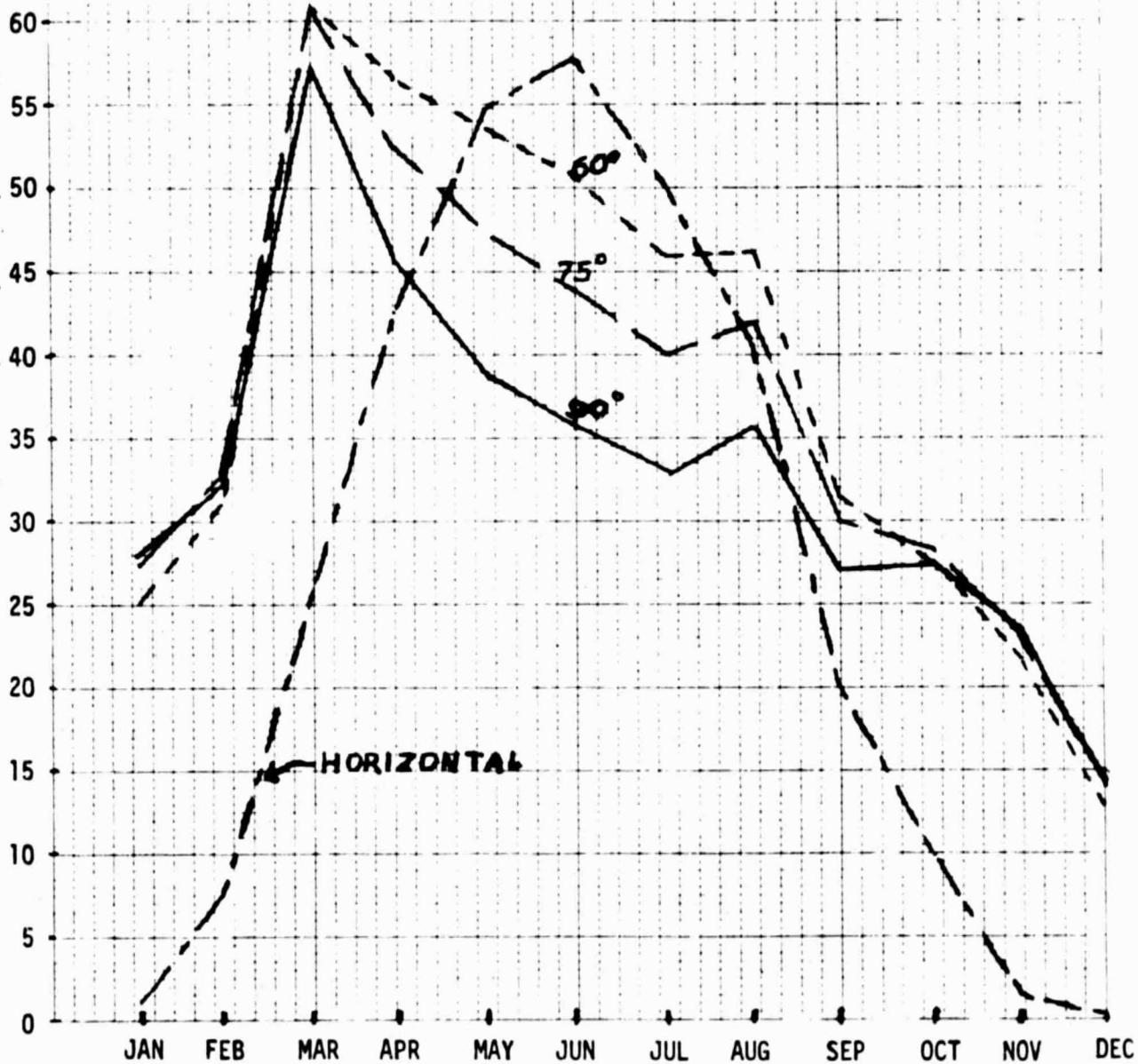


FIGURE 2. AVAILABLE SOLAR ENERGY

	Average Monthly Temp.	\bar{K}_t *	Insolation on Horizontal (10^3 BTU/FT ² / Month	Heating Degree Days
January	-11°F	0.64	2.2	2359
February	- 2	0.56	7.8	1901
March	9	0.67	26.6	1739
April	30	0.65	42.5	1068
May	46	0.55	54.5	555
June	57	0.53	58.2	222
July	59	0.49	50.7	171
August	54	0.46	41.4	332
September	43	0.42	20.3	642
October	27	0.42	9.8	1203
November	3	0.47	3.0	1833
December	- 8	0.46	0.7	2254

Table 1. Monthly Summary of Climatic Conditions for Fairbanks, Alaska

* Fraction of extraterrestrial radiation transmitted through the atmosphere.

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BUILDING HEATING REQUIREMENTS

The building heat loss calculations and present HVAC system design and operational modes were reviewed for the following purposes:

- o determine the heat loss rate of the building.
- o determine the methods utilized by the HVAC system in meeting the various building heating loads
- o identify HVAC system loads and/or modes of operation for which solar provided heat could be effectively utilized

The overall heat loss rate (U_o) of the main building and motor pool shop including makeup air ventilation was calculated as approximately 25,900 BTU/HR-°F. The internal heat generated by lights and people was determined to be an average of $4(10^6)$ BTU/day. An assumption was made that 50 percent of this heat went to offset heat losses and the balance became a heat gain to the cooling subsystem.

A breakdown of the HVAC system is basically as follows:

- o Boiler (Oil Fired)
 - Lower floor (unit heaters)
 - Stairways and vestibules (unit heaters)
 - Motor Pool Shop (unit heaters; floor coils, vent heat exchanger)
 - Make-up Air and Vent Subsystem (Vent Heat Exchange)

- Parking Garage (liquid to air heat exchanger)
 - Loading Dock (unit heaters)
 - Supplemental Heat to Heat Recovery System (L to L Heat Exchanger)
 - Hot Water (L to L Heat Exchanger)
- o Heat Recovery System (with water source tank)
- Water to air Heat Pumps on 1, 2, and 3 floors (100+ units)
 - Air conditioners for 1, 2, and 3 floors (3 units)
 - Hot water (L to L Heat Exchanger)

Initially, the heat recovery system, make-up air and vent subsystem, and motor pool shop (floor coils, vent heat exchanger) were selected as promising areas for a retrofit type interface with a liquid storage solar system. The heat recovery system's net load at the source tank, where

$$\text{net load} = \text{AC load (in)} - \text{heat pump load (out)},$$

could not be established from available information. The average monthly loads on the total HVAC system, on the main building unit heater, on the main building make-up air and vent subsystem (HV3), and on the Motor Pool Shop floor coil and vent subsystems are listed in Table 2.

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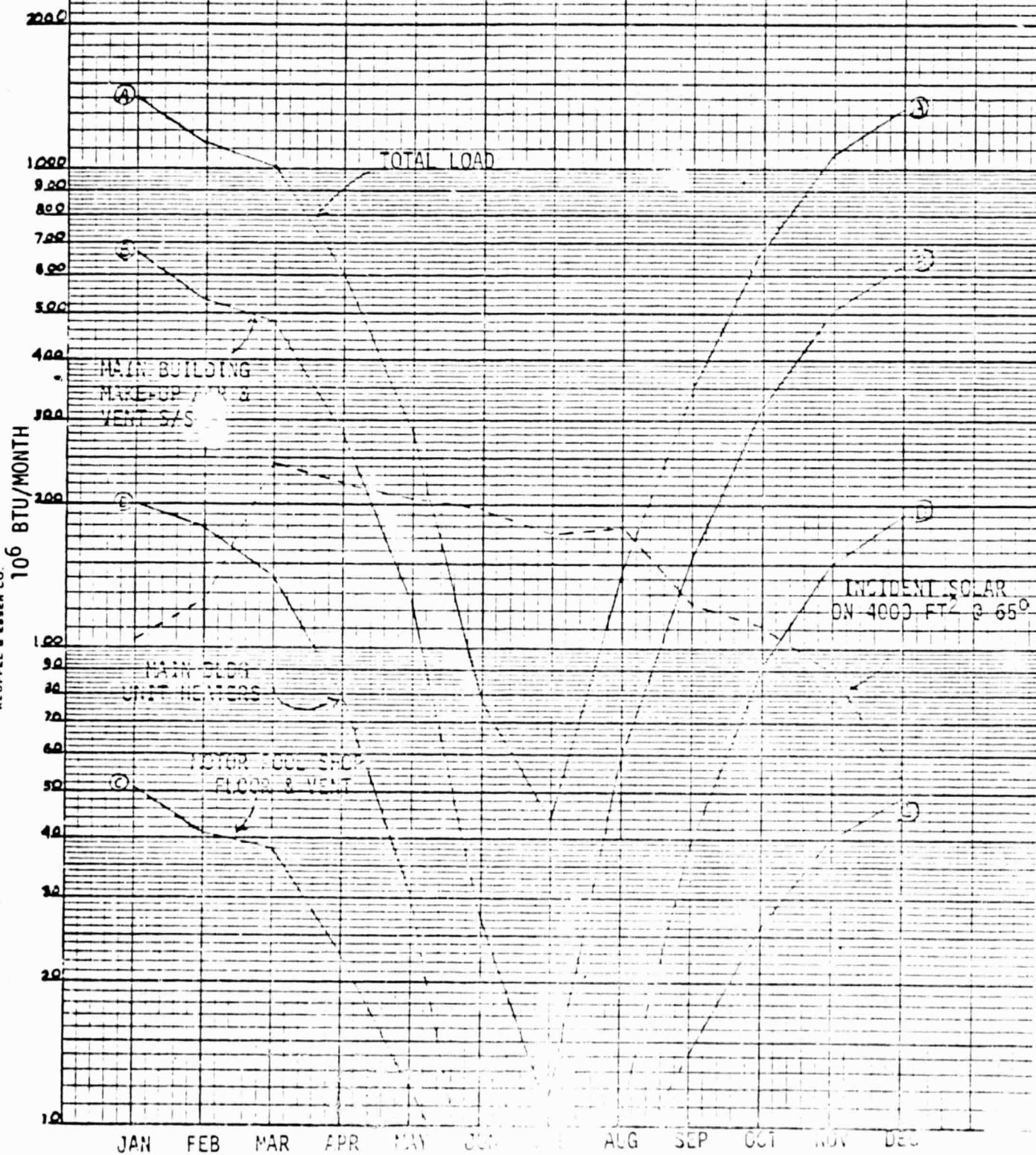
<u>Month</u>	<u>Total HVAC System (MBTU)</u>	<u>Main Bldg. Vent (MBTU)</u>	<u>Motor Pool Shop Vent & Floor (MTBU)</u>	<u>Main Bldg. Unit Heater (MTBU)</u>
January	1404	667	51	200
February	1126	534	41	179
March	1019	481	38	142
April	604	281	23	79
May	283	126	12	30
June	78	27	5	4
July	44	11	4	3
August	144	59	7	10
September	339	154	14	39
October	685	320	26	91
November	1079	511	40	151
December	<u>1339</u>	<u>636</u>	<u>49</u>	<u>190</u>
Total	8116	3809	311	1118

Table 2 - Average Building Heating Loads

Figure 3 presents the heat load profiles given in Table 2 versus the total incident solar energy on 4000 square feet of collector array at a 65° tilt angle. The efficiency of converting the incident energy into useable thermal energy varies from month to month and will be discussed later.

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FIGURE 3. SOLAR VS. HEATING LOADS



Key to the performance of a solar energy system are the parameters associated with the collectors and the heat transfer and storage fluid.

A high performance liquid flatplate collector, such as the Lennox Model LSC 18-1, was selected as the best type of collector for this application. Tracking collectors were eliminated because of operational risks caused by severe temperature extremes plus the ice and snow loading problems expected with a mechanical system. System interface difficulties and high duct work costs made air collectors to be unsuitable for this application.

A liquid flatplate collector using ethylene glycol/water (60/40) heat transfer and storage fluid was most compatible in interfacing with the present HVAC system. A high performance collector is recommended over a lower performance collector in order to realize the cost savings associated with the labor rates in use during array construction. Higher performance collectors allow smaller arrays for the same amount of collected energy. Thus, the additional hardware money spent for performance will be saved in construction costs.

Collector parameter values (see Figure 4) for the Lennox, a typical high performance unit, were utilized during the collector array tilt and sizing investigations. An energy storage factor of two gallons per square foot of effective collector area was used. The building loads discussed in an earlier section (Building Heating Requirements) were included in this analysis. The F-CHART program developed at the Solar Energy Laboratory of the University of Wisconsin was used as the primary analysis tool.

A brief description of this program inputs and outputs is provided in the following paragraphs. Figures 4 and 5 present the input listing and thermal printcut for a typical run.

1 INPUT ERROR, TRY AGAIN
1

CODE	VARIABLE DESCRIPTION	VALUE	UNITS
1	AIR SYSTEM#1, LIQUID SYSTEM#2	2.00	
2	COLLECTOR AREA	4000.00	FT2
3	FRPRIME-TAU-ALPHA PRODUCTXNORMAL INCIDENCE	0.74	
4	FRPRIME-UL PRODUCT	0.55	BTU/H-F-F2
5	NUMBER OF TRANSPARENT COVERS	2.00	
6	COLLECTOR SLOPE	65.00	DEGREES
7	AZIMUTH ANGLE XE.G. SOUTH#0, WEST#90	0.00	DEGREES
8	STORAGE CAPACITY	15.00	BTU/F-F2
9	EFFECTIVE BUILDING UA	12500.00	BTU/HR-F
10	CONSTANT DAILY BLDG HEAT GENERATION	*****	BTU/DAY
11	HOT WATER USAGE	0.0	GAL/DAY
12	WATER SET TEMPERATURE	140.00	F
13	WATER MAIN TEMPERATURE	51.80	F
14	CITY CALL NUMBER	34.00	
15	THERMAL PRINT OUT BY MONTH#1, BY YEAR#2	1.00	
16	ECONOMIC ANALYSIS YES#1, NO#2	2.00	
TYPE IN CODE NUMBER AND NEW VALUE			

* VALUE LARGER THAN SPACE ALLOCATED
ACTUAL VALUE = 2,000,000 BTU/DAY

Figure 4. Input Listing

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F FAIRBANKS      HV      64.49

***THERMAL ANALYSIS***
TIME PERCENT SOLAR  INCIDENT SOLAR  HEATING  WATER  DEGREE  AMBIENT
      SOLAR  (MBTU)  (MBTU)  (MBTU)  LOAD  (F-DAY)  TEMP
      (F)
JAN      7.4    104.25  667.39    0.0    2359.  -11.
FEB     12.7    127.47  533.91    0.0    1901.   -2.
MAR     29.2    245.19  451.41    0.0    1739.   9.
APR     42.2    222.16  281.40    0.0    1068.  30.
MAY     71.9    205.45  126.20    0.0    555.  46.
JUN    100.0    194.79   27.60    0.0    222.  57.
JUL    100.0    176.89   11.00    0.0    171.  59.
AUG    100.0    130.57   59.31    0.0    332.  54.
SEP     38.5    124.06  153.60    0.0    642.  43.
OCT     17.5    111.84  320.60    0.0    1203.  27.
NOV      8.1     99.56  510.90    0.0    1933.   3.
DEC      2.3     53.87  635.89    0.0    2254.  -8.
YR     19.3    1836.10 3809.20    0.0    14279.

TYPE IN CODE NUMBER AND NEW VALUE

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Figure 5. Thermal Analysis Printout

- o The meteorological data required to use the F-CHART method are: the long term monthly average of daily total solar radiation on a horizontal surface, the long term monthly average ambient temperature, and the long term monthly average heating degree days (65°F base).
- o The solar energy system data needed for the F-CHART method includes: The $F_R U_L$ and $F_R(\tau\alpha)$ products for the collector (which are the slope and intercept of collector efficiency versus $(T_{in} - T_{ambient})/(\text{incident radiation})$ curves); the effectiveness of heat exchangers between collector and tank (for liquid-based systems); the storage capacity per unit area of collector; and the orientation of the collector.
- o The building heating load is incorporated either by specifying the monthly load (calculated by any standard technique), or by specifying the building overall loss coefficient (energy-per-degree-day concept), which is the design heating load divided by the design temperature difference. In addition, a service hot water load can be added to the heating load.
- o Given these numbers, the fraction of monthly total loads, and the fraction of the annual loads to be carried by solar energy can readily be determined for any collector area.

The collector tilt angle sensitivity was evaluated using the main building vent subsystem load profile and 8,000 square feet of collector area. Tilt angles of 0, 60, 65, 70, 75, 80, and 90 degrees were examined. The resulting thermal analysis is presented in Figures 6 through 12 respectively. Annual solar contribution for each case is presented at the bottom of the first column. The highest percent solar contribution was obtained at 70 degrees of tilt. The variations at 65 and 75 degrees were slightly lower. These conclusions are valid for other collector areas.

CODE	VARIABLE DESCRIPTION	VALUE	UNITS
1	AIR SYSTEM-1 LIQUID SYSTEM-2	2.00	PI2
2	COLLECTOR AREA	800.00	PI2
3	EXPOSED TRANSPARENT COVERS	0.55	BTU-H-F-F2
4	NUMBER OF TRANSPARENT COVERS	2.00	PI2
5	COLLECTOR SLOPE (E.G. SOUTH-0, WEST-90)	0.00	DEGREES
6	AIR FLOW RATE (E.G. SOUTH-0, WEST-90)	2.00	DEGREES
7	STORAGE CAPACITY	15.00	BTU-H-F-F2
8	EFFECTIVE BUILDING UA	1250.00	BTU-H-F-F2
9	CONSTANT DAILY BLDG HEAT GENERATION	140.00	BTU-H-F-F2
10	HOT WATER USAGE	1.40	BTU-H-F-F2
11	WATER SET TEMPERATURE	51.00	F
12	WATER MAIN TEMPERATURE	34.00	F
13	CITY CALL NUMBER	1.00	BY YEAR-2
14	THERMAL PRINT OUT BY MONTH-1, BY YEAR-2	1.00	BY YEAR-2
15	ECONOMIC ANALYSIS YES-1, NO-2	2.00	TYPE IN CODE NUMBER AND NEW VALUE
16	TYPE IN CODE NUMBER AND NEW VALUE		

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FWPBMH: HK 64.42

TIME	PERCENT INCIDENT SOLAR	HEATING LOAD (MBTU)	WATER LOAD (MBTU)	DEGREE AMBIENT DAYS (F-DAY)	TEMP (F)
JAN	0.0	12.36	0.0	2359	-11
FEB	0.0	66.39	0.0	1901	-12
MAR	2.0	53.81	0.0	1720	0
APR	16.0	48.41	0.0	1068	30
MAY	46.0	30.25	0.0	555	46
JUN	100.0	45.76	0.0	222	59
JUL	100.0	45.76	0.0	171	54
AUG	100.0	33.50	0.0	332	47
SEP	27.7	162.62	0.0	642	37
OCT	0.0	72.53	0.0	1203	27
NOV	0.0	23.86	0.0	1833	3
DEC	0.0	5.48	0.0	2264	-8
YR	11.6	2541.07	0.0	14279	

TYPE IN CODE NUMBER AND NEW VALUE

Figure 6. 0° Tilt Angle

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CODE UMR:FILE DESCRIPTION VALUE UNIT
 1 AIR SYSTEM=1A LIQUID SYSTEM=2 0.00 F
 2 COLLECTOR AREA=1A 500.00 F
 3 PRIME-1A-1A PRODUCT(NORMAL INCIDENCE) 0.74 BTU H-F-E
 4 PRIME-1A-1A PRODUCT 0.55 BTU H-F-E
 5 NUMBER OF TRANSPARENT COVERS 2.00 DEGREES
 6 COLLECTOR SLOPE 0.00 DEGREES
 7 AIR FLOW ANGLE(E.G. SOUTH=0, WEST=90) 15.00 BTU H-F-E
 8 STORAGE CAPACITY 1200.00 BTU H-F-E
 9 EFFECTIVE DAILY BLDG HEAT GENERATION 0.00 CAL-DAY
 10 CONSTANT DAILY BLDG HEAT GENERATION 140.00 F
 11 HOT WATER USAGE 51.80 F
 12 WATER SET TEMPERATURE 34.00 F
 13 WATER HALL TEMPERATURE 1.00 F
 14 CITY CALL NUMBER 1.00 F
 15 THERMAL PRINT OUT BY MONTH=1, BY YEAR=2 2.00 F
 16 ECONOMIC ANALYSIS YES=1, NO=2 2.00 F
 TYPE IN CODE NUMBER AND NEW VALUE
 PAIRERINS MK 64.49
 THERMAL ANALYSIS
 TIME PERCENT INCIDENT HEATING LATER DEGREE AMBIENT
 SOLAR LOAD (F) DAYS TEMP
 (BTU) (BTU) (F) (F) (F)
 JAN 13.3 200.00 667.30 0.0 2359. -11.
 FEB 23.2 248.77 533.91 0.0 1901. -2.
 MAR 52.6 486.75 481.41 0.0 1739. 9.
 APR 73.0 452.31 281.40 0.0 1068. 30.
 MAY 100.0 435.57 126.20 0.0 1555. 45.
 JUN 100.0 436.17 127.60 0.0 222. 57.
 JUL 100.0 367.81 11.00 0.0 171. 59.
 AUG 100.0 370.88 59.31 0.0 332. 54.
 SEP 66.1 220.04 153.60 0.0 642. 43.
 OCT 31.7 220.03 330.60 0.0 1202. 27.
 NOV 14.5 173.11 50.00 0.0 1833. 3.
 DEC 4.0 103.39 635.80 0.0 2254. -3.
 YR 31.5 3705.52 3809.20 0.0 14279. -0.
 TYPE IN CODE NUMBER AND NEW VALUE

Figure 7. 60° Tilt Angle


```

CODE      UNPRINTE DESCRIPTION      VALUE UNITS
1  AIR SYSTEM-1-LEG.                3.00    FT2
2  COLLECTOR-1-LEG.                 300.00    FT2
3  FRACTIONAL PRODUCT(NORMAL INCIDENCE) 0.00
4  FRACTIONAL PRODUCT                0.00
5  FRACTIONAL TRANSPARENT COVERS      0.00
6  NUMBER OF TRANSPARENT COVERS      70.00
7  COLLECTOR SLOPE (E.G. SOUTH=0, WEST=90) 0.00
8  ALTITUDE ANGLE (E.G. SOUTH=0, WEST=90) 15.00
9  STORAGE CAPACITY                  12500.00
10  EFFECTIVE BUILDING UA            1111.11
11  CONSTANT DAILY BLDG HEAT GENERATION 140.00
12  HOT WATER USAGE                  51.80
13  WATER SET TEMPERATURE            34.00
14  CITY CAL NUMBER                   1.00
15  THERMAL PRINT OUT BY MONTH=1, BY YEAR=2
16  ECONOMIC ANALYSIS YES=1, NO=2
TYPE IN CODE NUMBER AND NEW VALUE

FAIRBANKS      64  64.43

1111-THERMAL ANALYSIS
TIME PERCENT INCIDENT HEATING WATER DEGREE AMBIENT
SOLAR      LOAD      (F-DAY) (F)
(MBTU)      (MBTU)      DAYS
JAN  15.2  214.77  667.39  0.0  2550.  -11.
FEB  24.8  350.29  523.91  0.0  1991.  -2.
MAR  53.9  433.63  481.41  0.0  1739.  9.
APR  70.7  433.61  281.49  0.0  1098.  30.
MAY  100.0  334.21  126.29  0.0  555.  46.
JUN  100.0  371.33  127.60  0.0  222.  57.
JUL  100.0  338.20  11.00  0.0  171.  54.
AUG  100.0  339.47  159.21  0.0  332.  43.
SEP  94.1  244.72  153.60  0.0  842.  27.
OCT  33.1  225.81  323.60  0.0  1293.  3.
NOV  19.4  183.83  519.90  0.0  1333.  -8.
DEC  5.2  111.27  635.89  0.0  1254.
YR  32.4  3617.13  3809.20  0.0  14270.
TYPE IN CODE NUMBER AND NEW VALUE

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1.3 x 10⁶

Figure 9. 70° Tilt Angle

13 x 104

CODE	USAGE DESCRIPTION	VALUE	UNIT
1	WATER HEAT LIQUID SYSTEM-2	2.00	
2	COLLECTOR AREA	800.00	SQ FT
3	PERCENT TRANSPARENT COVERS	0.00	%
4	PERCENT TRANSPARENT COVERS	0.00	%
5	PERCENT TRANSPARENT COVERS	0.00	%
6	PERCENT TRANSPARENT COVERS	0.00	%
7	PERCENT TRANSPARENT COVERS	0.00	%
8	PERCENT TRANSPARENT COVERS	0.00	%
9	PERCENT TRANSPARENT COVERS	0.00	%
10	PERCENT TRANSPARENT COVERS	0.00	%
11	PERCENT TRANSPARENT COVERS	0.00	%
12	PERCENT TRANSPARENT COVERS	0.00	%
13	PERCENT TRANSPARENT COVERS	0.00	%
14	PERCENT TRANSPARENT COVERS	0.00	%
15	PERCENT TRANSPARENT COVERS	0.00	%
16	PERCENT TRANSPARENT COVERS	0.00	%
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25	PERCENT TRANSPARENT COVERS	0.00	%
26	PERCENT TRANSPARENT COVERS	0.00	%
27	PERCENT TRANSPARENT COVERS	0.00	%
28	PERCENT TRANSPARENT COVERS	0.00	%
29	PERCENT TRANSPARENT COVERS	0.00	%
30	PERCENT TRANSPARENT COVERS	0.00	%
31	PERCENT TRANSPARENT COVERS	0.00	%
32	PERCENT TRANSPARENT COVERS	0.00	%
33	PERCENT TRANSPARENT COVERS	0.00	%
34	PERCENT TRANSPARENT COVERS	0.00	%
35	PERCENT TRANSPARENT COVERS	0.00	%
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39	PERCENT TRANSPARENT COVERS	0.00	%
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41	PERCENT TRANSPARENT COVERS	0.00	%
42	PERCENT TRANSPARENT COVERS	0.00	%
43	PERCENT TRANSPARENT COVERS	0.00	%
44	PERCENT TRANSPARENT COVERS	0.00	%
45	PERCENT TRANSPARENT COVERS	0.00	%
46	PERCENT TRANSPARENT COVERS	0.00	%
47	PERCENT TRANSPARENT COVERS	0.00	%
48	PERCENT TRANSPARENT COVERS	0.00	%
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98	PERCENT TRANSPARENT COVERS	0.00	%
99	PERCENT TRANSPARENT COVERS	0.00	%
100	PERCENT TRANSPARENT COVERS	0.00	%

TYPE IN CODE NUMBER AND NEW VALUE

FILE# 5 AC 64.49

TIME	PERCENT INCIDENT SOLAR	HEATING LOAD (BTU)	WATER LOAD (GAL)	DEGREE DAYS	DIFFERENTIAL
JAN	15.22	210.43	0.00	2352	-11
FEB	15.22	210.43	0.00	1739	0
MAR	15.22	210.43	0.00	1068	30
APR	15.22	210.43	0.00	555	57
MAY	15.22	210.43	0.00	222	54
JUN	15.22	210.43	0.00	171	54
JUL	15.22	210.43	0.00	171	54
AUG	15.22	210.43	0.00	171	54
SEP	15.22	210.43	0.00	171	54
OCT	15.22	210.43	0.00	171	54
NOV	15.22	210.43	0.00	171	54
DEC	15.22	210.43	0.00	171	54
YR	15.22	210.43	0.00	171	54

TYPE IN CODE NUMBER AND NEW VALUE

Figure 10. 75° Tilt Angle

[illegible]

21

CODE	VARIABLE DESCRIPTION	VALUE	UNIT
1	410 SYSTEM-1 LIQUID SYSTEM-2	1.00	1.00
2	COLLECTOR AREA	6000.00	FT ²
3	FRABTIME-10 PRODUCT(NORMAL INCIDENCE)	0.24	
4	FRABTIME-10 PRODUCT	0.55	
5	NUMBER OF TRANSPARENT COVERS	2.00	
6	NUMBER OF TRANSPARENT COVERS	2.00	
7	COLLECTOR SLOPE (E.G. SOUTH=0, WEST=90)	0.00	DEGREES
8	COLLECTOR SLOPE (E.G. SOUTH=0, WEST=90)	0.00	DEGREES
9	STORAGE CAPACITY	15.00	8-LY-FT ²
10	EFFECTIVE BUILDING UA	1250.00	8-LY-FT ²
11	CONSTANT DAILY BLDG HEAT GENERATION	1000.00	BTU/DAY
12	HOT WATER USAGE	140.00	FT ³
13	WATER SET TEMPERATURE	51.83	F
14	CITY CAL NUMBER	34.00	
15	THERMAL PRINT OUT BY MONTH-1 BY YEAR-2	1.00	
16	ECONOMIC ANALYSIS YES-1, NO-2	2.00	
17	TYPE IN CODE NUMBER AND NEW VALUE		
18	FAIRBANKS AK 64.49		
19	HEATING ANALYSIS		
20	PERCENT INCIDENT SOLAR		
21	HEATING LOAD (BTU)		
22	WATER LOAD (GAL)		
23	DEGREE AMBIENT		
24	TEMP		
25	TIME		
26	JAN	19.4	
27	FEB	24.8	
28	MAR	47.3	
29	APR	75.8	
30	MAY	100.0	
31	JUN	100.0	
32	JUL	100.0	
33	AUG	100.0	
34	SEP	55.0	
35	OCT	31.3	
36	NOV	17.3	
37	DEC	6.0	
38	YR	30.2	
39	TYPE IN CODE NUMBER AND NEW VALUE		

Figure 12. 90° Tilt Angle

Various collector array sizes were analyzed to determine affects on solar contribution. The main building vent load and the total HVAC system load was evaluated at 4000, 6000, 8000, and 10,000 square feet of collector array at a tilt of 65 degrees (Figures 8 and 13 through 19). The load for the motor pool shop vent and heated floor was analyzed for an array of 1000, 2000 and 4000 square feet (Figures 20 through 22).

Although increasing effective collector area increases the solar contribution, it also increases solar system purchase and installation costs, such that final determination of an array size must result from performance/cost studies.

CODE	VARIABLE DESCRIPTION	VALUE	UNIT
1	AIR SYSTEM-1 LIQUID SYSTEM-2	2.00	
2	COLLECTOR AREA	400.00	FT ²
3	APPROXIMATE-16 AREA PRODUCT (NORMAL INCIDENCE)	0.55	BTU H F-FT ²
4	APPROXIMATE-16 PRODUCT	0.55	BTU H F-FT ²
5	NUMBER OF TRANSPARENT COVERS	0.00	DEGREES
6	COLLECTOR SLOPE	0.00	DEGREES
7	COLLECTOR ANGLE (E.G. SOUTH-0, WEST-90)	0.00	BTU H F-FT ²
8	STORAGE CAPACITY	15.00	BTU H F-FT ²
9	EFFECTIVE BUILDING UA	1350.00	BTU H F-FT ²
10	CONSTANT DAILY BLDG HEAT GENERATION	0.00	GAL/DAY
11	HOT WATER USAGE	140.00	F
12	WATER SET TEMPERATURE	51.00	F
13	WATER MAIN TEMPERATURE	34.00	F
14	CITY CALL NUMBER	1.00	
15	THERMAL PRINT OUT BY MONTH-1 BY YEAR-2	2.00	
16	ECONOMIC ANALYSIS YES-1, NO-2		
TYPE IN CODE NUMBER AND NEW VALUE			
FWIFEMHS AK 64.43			

TYPE IN CODE NUMBER AND NEW VALUE	TIME PERCENT IN SOLAR	HEATING LOAD (MBTU)	WATER LOAD (MBTU)	DEGREE DAYS (F-DAY)	AMBIENT TEMP (F)
JAN	7.4	667.39	0.00	2359	-11
FEB	12.7	573.31	0.00	1739	-2
MAR	23.2	481.41	0.00	1068	30
APR	42.2	281.49	0.00	555	46
MAY	71.3	126.29	0.00	222	57
JUN	100.0	11.00	0.00	171	59
JUL	100.0	11.00	0.00	171	59
AUG	38.5	153.60	0.00	642	54
SEP	17.5	320.60	0.00	1803	43
OCT	2.1	510.00	0.00	2359	27
NOV	2.1	635.89	0.00	2359	-8
DEC	2.1	635.89	0.00	2359	-8
VR	18.3	3809.20	0.00	14879	

Figure 13. Main Building Vent Load (4000 FT²)

ORIGINAL PAGE IS
OF POOR QUALITY

CODE	PARAMETER DESCRIPTION	VALUE	UNIT
1	AIR SYSTEM AREA	6000.00	SQ. FT.
2	COLLECTOR AREA	6000.00	SQ. FT.
3	COLLECTOR AREA PRODUCT/NORMAL INCIDENCE	6000.00	SQ. FT.
4	PRIME-FOUR PRODUCT	6000.00	SQ. FT.
5	NUMBER OF TRANSPARENT COVERS	6000.00	SQ. FT.
6	COLLECTOR SLOPE	6000.00	DEGREES
7	COLLECTOR SLOPE (E.G. SOUTH=0, WEST=90)	6000.00	DEGREES
8	STORAGE CAPACITY	1500.00	B-TU
9	EFFECTIVE BUILDING UA	1500.00	B-TU
10	CONSTANT DAILY BLDG HEAT GENERATION	1500.00	B-TU
11	HOT WATER USAGE	140.00	FT-DAY
12	WATER SET TEMPERATURE	51.00	F
13	WATER MAIN TEMPERATURE	51.00	F
14	CITY CALL NUMBER	1.00	
15	THERMAL PRINT OUT BY MONTH=1, BY YEAR=2	1.00	
16	ECONOMIC ANALYSIS YES=1, NO=2	2.00	
TYPE IN CODE NUMBER AND NEW VALUE			
FAIRBANKS AK 64.42			

MONTH	PERCENT SOLAR	INCIDENT SOLAR (BTU)	HEATING LOAD (BTU)	LATER LOAD (BTU)	DEGREE DAYS (F-DAY)	ATMBT (F)
JAN	10.0	156.33	697.39	0.0	2359	-11
FEB	13.6	191.28	537.91	0.0	1901	-2
MAR	41.3	367.73	481.41	0.0	1739	0
APR	53.2	333.24	281.40	0.0	1068	30
MAY	62.2	303.17	126.20	0.0	555	46
JUN	100.0	203.18	127.60	0.0	222	57
JUL	100.0	265.33	11.00	0.0	171	59
AUG	100.0	270.86	59.31	0.0	332	54
SEP	53.4	186.19	153.60	0.0	1642	43
OCT	25.7	167.76	380.00	0.0	1203	27
NOV	11.3	134.34	510.00	0.0	1837	3
DEC	3.5	130.80	655.80	0.0	2354	-3
YR	26.2	2754.15	3800.20	0.0	14270	-8

TYPE IN CODE NUMBER AND NEW VALUE

Figure 14. Main Building Vent Load (6000 FT²)

Figure 15. Main Building Vent Load (1000 FT²)

ORIGINAL PAGE IS
OF POOR QUALITY

CODE	VARIABLE DESCRIPTION	VALUE	UNITS
1	AIR SYSTEM-1, LIQUID SYSTEM-2	2.00	1.00
2	COLOR-1, AREA-2	4.00	1.00
3	COLOR-1, AREA-2	2.00	1.00
4	APPROXIMATE-1, PRODUCT(NORMAL INCIDENCE)	2.00	1.00
5	APPROXIMATE-1, PRODUCT(NORMAL INCIDENCE)	2.00	1.00
6	NUMBER OF TRANSPARENT COVERS	2.00	1.00
7	COLLECTOR SLOPE	2.00	1.00
8	COLLECTOR SLOPE (E.G. SOUTH-0, WEST-90)	2.00	1.00
9	STORAGE CAPACITY	15.00	1.00
10	EFFECTIVE BUILDING AREA	25.00	1.00
11	CONSTANT DAILY BLDG HEAT GENERATION	2.00	1.00
12	HOT WATER USAGE	142.00	1.00
13	WATER SET TEMPERATURE	51.00	1.00
14	CITY CALL NUMBER	34.00	1.00
15	THERMAL PRINT OUT BY MONTH-1, BY YEAR-2	1.00	1.00
16	ECONOMIC ANALYSIS YES-1, NO-2	2.00	1.00
17	TYPE IN CODE NUMBER AND NEW VALUE		
FAIRBANKS	AK		
1	TIME PERIOD	1.00	1.00
2	TIME PERIOD	1.00	1.00
3	TIME PERIOD	1.00	1.00
4	TIME PERIOD	1.00	1.00
5	TIME PERIOD	1.00	1.00
6	TIME PERIOD	1.00	1.00
7	TIME PERIOD	1.00	1.00
8	TIME PERIOD	1.00	1.00
9	TIME PERIOD	1.00	1.00
10	TIME PERIOD	1.00	1.00
11	TIME PERIOD	1.00	1.00
12	TIME PERIOD	1.00	1.00
13	TIME PERIOD	1.00	1.00
14	TIME PERIOD	1.00	1.00
15	TIME PERIOD	1.00	1.00
16	TIME PERIOD	1.00	1.00
17	TIME PERIOD	1.00	1.00
18	TIME PERIOD	1.00	1.00
19	TIME PERIOD	1.00	1.00
20	TIME PERIOD	1.00	1.00
21	TIME PERIOD	1.00	1.00
22	TIME PERIOD	1.00	1.00
23	TIME PERIOD	1.00	1.00
24	TIME PERIOD	1.00	1.00
25	TIME PERIOD	1.00	1.00
26	TIME PERIOD	1.00	1.00
27	TIME PERIOD	1.00	1.00
28	TIME PERIOD	1.00	1.00
29	TIME PERIOD	1.00	1.00
30	TIME PERIOD	1.00	1.00
31	TIME PERIOD	1.00	1.00
32	TIME PERIOD	1.00	1.00
33	TIME PERIOD	1.00	1.00
34	TIME PERIOD	1.00	1.00
35	TIME PERIOD	1.00	1.00
36	TIME PERIOD	1.00	1.00
37	TIME PERIOD	1.00	1.00
38	TIME PERIOD	1.00	1.00
39	TIME PERIOD	1.00	1.00
40	TIME PERIOD	1.00	1.00
41	TIME PERIOD	1.00	1.00
42	TIME PERIOD	1.00	1.00
43	TIME PERIOD	1.00	1.00
44	TIME PERIOD	1.00	1.00
45	TIME PERIOD	1.00	1.00
46	TIME PERIOD	1.00	1.00
47	TIME PERIOD	1.00	1.00
48	TIME PERIOD	1.00	1.00
49	TIME PERIOD	1.00	1.00
50	TIME PERIOD	1.00	1.00
51	TIME PERIOD	1.00	1.00
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54	TIME PERIOD	1.00	1.00
55	TIME PERIOD	1.00	1.00
56	TIME PERIOD	1.00	1.00
57	TIME PERIOD	1.00	1.00
58	TIME PERIOD	1.00	1.00
59	TIME PERIOD	1.00	1.00
60	TIME PERIOD	1.00	1.00
61	TIME PERIOD	1.00	1.00
62	TIME PERIOD	1.00	1.00
63	TIME PERIOD	1.00	1.00
64	TIME PERIOD	1.00	1.00
65	TIME PERIOD	1.00	1.00
66	TIME PERIOD	1.00	1.00
67	TIME PERIOD	1.00	1.00
68	TIME PERIOD	1.00	1.00
69	TIME PERIOD	1.00	1.00
70	TIME PERIOD	1.00	1.00
71	TIME PERIOD	1.00	1.00
72	TIME PERIOD	1.00	1.00
73	TIME PERIOD	1.00	1.00
74	TIME PERIOD	1.00	1.00
75	TIME PERIOD	1.00	1.00
76	TIME PERIOD	1.00	1.00
77	TIME PERIOD	1.00	1.00
78	TIME PERIOD	1.00	1.00
79	TIME PERIOD	1.00	1.00
80	TIME PERIOD	1.00	1.00
81	TIME PERIOD	1.00	1.00
82	TIME PERIOD	1.00	1.00
83	TIME PERIOD	1.00	1.00
84	TIME PERIOD	1.00	1.00
85	TIME PERIOD	1.00	1.00
86	TIME PERIOD	1.00	1.00
87	TIME PERIOD	1.00	1.00
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89	TIME PERIOD	1.00	1.00
90	TIME PERIOD	1.00	1.00
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92	TIME PERIOD	1.00	1.00
93	TIME PERIOD	1.00	1.00
94	TIME PERIOD	1.00	1.00
95	TIME PERIOD	1.00	1.00
96	TIME PERIOD	1.00	1.00
97	TIME PERIOD	1.00	1.00
98	TIME PERIOD	1.00	1.00
99	TIME PERIOD	1.00	1.00
100	TIME PERIOD	1.00	1.00

Figure 16. Total HVAC System Load (4000 FT²)

CODE	VARIABLE DESCRIPTION	VALUE	UNIT
1	SYSTEM TYPE	2	2.0 X 10 ⁶
2	SYSTEM TYPE	2	2.0 X 10 ⁶
3	SYSTEM TYPE	2	2.0 X 10 ⁶
4	SYSTEM TYPE	2	2.0 X 10 ⁶
5	SYSTEM TYPE	2	2.0 X 10 ⁶
6	SYSTEM TYPE	2	2.0 X 10 ⁶
7	SYSTEM TYPE	2	2.0 X 10 ⁶
8	SYSTEM TYPE	2	2.0 X 10 ⁶
9	SYSTEM TYPE	2	2.0 X 10 ⁶
10	SYSTEM TYPE	2	2.0 X 10 ⁶
11	SYSTEM TYPE	2	2.0 X 10 ⁶
12	SYSTEM TYPE	2	2.0 X 10 ⁶
13	SYSTEM TYPE	2	2.0 X 10 ⁶
14	SYSTEM TYPE	2	2.0 X 10 ⁶
15	SYSTEM TYPE	2	2.0 X 10 ⁶
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96	SYSTEM TYPE	2	2.0 X 10 ⁶
97	SYSTEM TYPE	2	2.0 X 10 ⁶
98	SYSTEM TYPE	2	2.0 X 10 ⁶
99	SYSTEM TYPE	2	2.0 X 10 ⁶
100	SYSTEM TYPE	2	2.0 X 10 ⁶

TIME	PERCENT SOLAR	PERCENT INCIDENT SOLAR	HEATING LOAD (BTU)	WATER LOAD (GAL)	DEGREE DAYS	AMBIENT TEMP (F)
JAN	5.3	156.38	104.34	0.0	2350	-11
FEB	8.1	151.20	115.68	0.0	1901	-2
MAR	21.9	167.70	141.08	0.0	1730	3
APR	35.0	203.24	203.87	0.0	1068	30
MAY	50.0	233.17	283.66	0.0	553	45
JUN	60.0	233.18	78.00	0.0	232	57
JUL	60.0	233.18	44.30	0.0	171	55
AUG	50.0	270.86	33.07	0.0	372	54
SEP	27.5	167.10	68.78	0.0	123	43
OCT	15.3	134.34	107.39	0.0	123	27
NOV	8.1	100.80	173.07	0.0	183	3
DEC	5.3	275.15	8145.82	0.0	1420	-8
YR	15.1	2754.15	8145.82	0.0	1420	-8

Figure 17. Total HVAC System Load (6000 FT²)

CODE	VARIABLE DESCRIPTION	VALUE	UNITS
1	AIR SYSTEM-1 LIQUID SYSTEM-2	2.00	F-2
2	COLLECTOR AREA	320.00	F-2
3	FRAPRIME-TU-MLEMA PRODUCT(NORMAL INCIDENCE)	0.74	
4	FRAPRIME-TU PRODUCT	0.55	B-TU-M-F-F2
5	NUMBER OF TRANSPARENT COVERS	5.00	
6	COLLECTOR SLOPE	65.00	DEGREES
7	COLLECTOR SLOPE (E.G. SOUTH=0, WEST=90)	0.00	DEGREES
8	AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90)	15.00	B-TU-M-F-F2
9	STORAGE CAPACITY	2550.00	B-TU-M-F-F2
10	EFFECTIVE BUILDING UA	2550.00	B-TU-M-F-F2
11	CONSTANT DAILY BLDG HEAT GENERATION	0.00	CAL/DAY
12	HOT WATER USAGE	140.00	F
13	WATER SET TEMPERATURE	51.80	F
14	CITY CALL NUMBER	34.00	
15	THERMAL PRINT OUT BY MONTH-1 BY YEAR-2	1.00	
16	ECONOMIC ANALYSIS YES=1 NO=2	2.00	
TYPE IN CODE NUMBER AND NEW VALUE			
FAIRPEAKS AK 64.42			
HEAT THERMAL ANALYSIS			
TIME	PERCENT INCIDENT SOLAR RADIATION	WATER LOAD (MBTU)	DEGREE AT TEMP
JAN	7.0	208.51	2359. -11.
FEB	12.7	254.93	1901. -12.
MAR	23.9	492.33	1739. 0.
APR	33.9	444.31	1068. 30.
MAY	60.3	410.89	555. 40.
JUN	100.0	389.58	222. 57.
JUL	122.0	361.14	171. 59.
AUG	92.5	328.07	642. 47.
SEP	75.4	223.68	1203. 27.
OCT	16.4	179.13	1833. 3.
NOV	7.6	107.74	2254. -8.
DEC	2.2	3672.20	14279. 0.0
YR	10.9		
TYPE IN CODE NUMBER AND NEW VALUE			

Figure 18. Total HVAC System Load (8000 FT²)

CODE	VARIABLE DESCRIPTION	VALUE	UNITS	
1	AIR SYSTEM-1 LIQUID SYSTEM-2	1000.00	IT2	
2	COLLECTOR AREA	9.74	FT2	
3	FRAPRIME-TU-MULCH PRODUCT(NORMAL INCIDENCE)	0.55	BTU H-F-F2	
4	FRAPRIME-TU PRODUCT	0.55	BTU H-F-F2	
5	NUMBER OF TRANSPARENT COVERS	0.55	BTU H-F-F2	
6	COLLECTOR SLOPE	0.55	DEGREES	
7	AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90)	0.55	DEGREES	
8	STORAGE CAPACITY	15.00	BTU H-F-F2	
9	EFFECTIVE BUILDING UA	900.00	BTU H-F-F2	
10	CONSTANT DAILY BLDG HEAT GENERATION	0.0	BTU/DAY	
11	HOT WATER USAGE	0.0	GAL/DAY	
12	WATER SET TEMPERATURE	140.00	F	
13	WATER MAIN TEMPERATURE	51.00	F	
14	CITY CALL NUMBER	34.00	F	
15	THERMAL PRINT OUT BY MONTH-1, BY YEAR-2	1.00		
16	ECONOMIC ANALYSIS YES-1, NO-2	2.00		
TYPE IN CODE NUMBER AND NEW VALUE				
FAIRBANKS AK 64.43				
HEAT THERMAL ANALYSIS				
TIME	PERCENT SOLAR	HEATING LOAD (MBTU)	WATER LOAD (MBTU)	DEGREE AMBIENT (F)
JAN	22.4	51.41	0.0	-11.
FEB	36.7	41.43	0.0	-2.
MAR	74.7	37.00	0.0	9.
APR	93.5	23.27	0.0	30.
MAY	100.0	12.00	0.0	46.
JUN	100.0	4.84	0.0	57.
JUL	100.0	3.73	0.0	69.
AUG	100.0	7.24	0.0	77.
SEP	70.0	13.00	0.0	54.
OCT	49.0	26.22	0.0	43.
NOV	23.0	38.04	0.0	27.
DEC	7.4	48.12	0.0	3.
YR	45.3	311.17	0.0	-8.
TYPE IN CODE NUMBER AND NEW VALUE				

Figure 20. Motor Pool Shop Vent and Floor Load (1000 FT²)

CODE	VARIABLE DESCRIPTION	VALUE	UNIT
1	AIR SYSTEM	1.00	
2	COLLECTOR	200.00	FT ²
3	EXHAUST	0.55	B-TU-F-E
4	EXHAUST	0.55	B-TU-F-E
5	EXHAUST	0.55	B-TU-F-E
6	EXHAUST	0.55	B-TU-F-E
7	EXHAUST	0.55	B-TU-F-E
8	EXHAUST	0.55	B-TU-F-E
9	EXHAUST	0.55	B-TU-F-E
10	EXHAUST	0.55	B-TU-F-E
11	EXHAUST	0.55	B-TU-F-E
12	EXHAUST	0.55	B-TU-F-E
13	EXHAUST	0.55	B-TU-F-E
14	EXHAUST	0.55	B-TU-F-E
15	EXHAUST	0.55	B-TU-F-E
16	EXHAUST	0.55	B-TU-F-E
17	EXHAUST	0.55	B-TU-F-E
18	EXHAUST	0.55	B-TU-F-E
19	EXHAUST	0.55	B-TU-F-E
20	EXHAUST	0.55	B-TU-F-E
21	EXHAUST	0.55	B-TU-F-E
22	EXHAUST	0.55	B-TU-F-E
23	EXHAUST	0.55	B-TU-F-E
24	EXHAUST	0.55	B-TU-F-E
25	EXHAUST	0.55	B-TU-F-E
26	EXHAUST	0.55	B-TU-F-E
27	EXHAUST	0.55	B-TU-F-E
28	EXHAUST	0.55	B-TU-F-E
29	EXHAUST	0.55	B-TU-F-E
30	EXHAUST	0.55	B-TU-F-E
31	EXHAUST	0.55	B-TU-F-E
32	EXHAUST	0.55	B-TU-F-E
33	EXHAUST	0.55	B-TU-F-E
34	EXHAUST	0.55	B-TU-F-E
35	EXHAUST	0.55	B-TU-F-E
36	EXHAUST	0.55	B-TU-F-E
37	EXHAUST	0.55	B-TU-F-E
38	EXHAUST	0.55	B-TU-F-E
39	EXHAUST	0.55	B-TU-F-E
40	EXHAUST	0.55	B-TU-F-E
41	EXHAUST	0.55	B-TU-F-E
42	EXHAUST	0.55	B-TU-F-E
43	EXHAUST	0.55	B-TU-F-E
44	EXHAUST	0.55	B-TU-F-E
45	EXHAUST	0.55	B-TU-F-E
46	EXHAUST	0.55	B-TU-F-E
47	EXHAUST	0.55	B-TU-F-E
48	EXHAUST	0.55	B-TU-F-E
49	EXHAUST	0.55	B-TU-F-E
50	EXHAUST	0.55	B-TU-F-E
51	EXHAUST	0.55	B-TU-F-E
52	EXHAUST	0.55	B-TU-F-E
53	EXHAUST	0.55	B-TU-F-E
54	EXHAUST	0.55	B-TU-F-E
55	EXHAUST	0.55	B-TU-F-E
56	EXHAUST	0.55	B-TU-F-E
57	EXHAUST	0.55	B-TU-F-E
58	EXHAUST	0.55	B-TU-F-E
59	EXHAUST	0.55	B-TU-F-E
60	EXHAUST	0.55	B-TU-F-E
61	EXHAUST	0.55	B-TU-F-E
62	EXHAUST	0.55	B-TU-F-E
63	EXHAUST	0.55	B-TU-F-E
64	EXHAUST	0.55	B-TU-F-E
65	EXHAUST	0.55	B-TU-F-E
66	EXHAUST	0.55	B-TU-F-E
67	EXHAUST	0.55	B-TU-F-E
68	EXHAUST	0.55	B-TU-F-E
69	EXHAUST	0.55	B-TU-F-E
70	EXHAUST	0.55	B-TU-F-E
71	EXHAUST	0.55	B-TU-F-E
72	EXHAUST	0.55	B-TU-F-E
73	EXHAUST	0.55	B-TU-F-E
74	EXHAUST	0.55	B-TU-F-E
75	EXHAUST	0.55	B-TU-F-E
76	EXHAUST	0.55	B-TU-F-E
77	EXHAUST	0.55	B-TU-F-E
78	EXHAUST	0.55	B-TU-F-E
79	EXHAUST	0.55	B-TU-F-E
80	EXHAUST	0.55	B-TU-F-E
81	EXHAUST	0.55	B-TU-F-E
82	EXHAUST	0.55	B-TU-F-E
83	EXHAUST	0.55	B-TU-F-E
84	EXHAUST	0.55	B-TU-F-E
85	EXHAUST	0.55	B-TU-F-E
86	EXHAUST	0.55	B-TU-F-E
87	EXHAUST	0.55	B-TU-F-E
88	EXHAUST	0.55	B-TU-F-E
89	EXHAUST	0.55	B-TU-F-E
90	EXHAUST	0.55	B-TU-F-E
91	EXHAUST	0.55	B-TU-F-E
92	EXHAUST	0.55	B-TU-F-E
93	EXHAUST	0.55	B-TU-F-E
94	EXHAUST	0.55	B-TU-F-E
95	EXHAUST	0.55	B-TU-F-E
96	EXHAUST	0.55	B-TU-F-E
97	EXHAUST	0.55	B-TU-F-E
98	EXHAUST	0.55	B-TU-F-E
99	EXHAUST	0.55	B-TU-F-E
100	EXHAUST	0.55	B-TU-F-E

Figure 21. Motor Pool Shop Vent and Floor Load (2,000 FT²)

CODE	VARIABLE DESCRIPTION	VALUE	UNIT		
1	AIR SYSTEM-1 LIQUID SYSTEM-2	2.00	FT ²		
2	COLLECTOR AREA	4000.00	FT ²		
3	EXPOSED SURF. PRODUCT(NORMAL INCIDENCE)	2.74	BTU/HR-FT ²		
4	EXPOSED SURF. PRODUCT	2.00	BTU/HR-FT ²		
5	NUMBER OF TRANSPARENT COVERS	5.00	DEGREES		
6	COLLECTOR SLOPE (E.G. SOUTH=0, WEST=90)	2.00	BTU/HR-FT ²		
7	ATTENUATION COEFFICIENT (E.G. SOUTH=0, WEST=90)	15.00	BTU/HR-FT ²		
8	STORAGE CAPACITY	938.00	BTU/HR-FT ²		
9	EFFECTIVE BUILDING UA	0.00	BTU/HR-FT ²		
10	CONSTANT DAILY BLDG HEAT GENERATION	0.00	BTU/HR-FT ²		
11	HOT WATER USAGE	51.00	F		
12	WATER SET TEMPERATURE	34.00	F		
13	WATER MAIN TEMPERATURE	51.00	F		
14	CITY CALL NUMBER	1	BY YEAR=2		
15	THERMAL PRINT OUT BY MONTH	1	BY YEAR=2		
16	ECONOMIC ANALYSIS	YES=1, NO=2			
17	TYPE IN CODE NUMBER AND NEW VALUE				
FAIRBANKS	AK	64.43			
SOUTHERN ANALYSIS: 1988					
TIME	PERCENT INCIDENT SOLAR	HEATING LOAD (MBTU)	WATER LOAD (GPD)	DEGREE DAYS (F-DAY)	ANNUAL TEMP
JAN	55.4	134.25	51.41	0.00	2350.
FEB	100.0	127.47	41.43	0.00	1501.
MAR	100.0	145.13	37.00	0.00	1730.
APR	100.0	222.16	23.27	0.00	1068.
MAY	100.0	205.45	12.05	0.00	555.
JUN	100.0	134.70	14.84	0.00	222.
JUL	100.0	176.89	3.73	0.00	171.
AUG	100.0	180.57	7.24	0.00	332.
SEP	100.0	124.00	13.99	0.00	642.
OCT	100.0	111.84	26.22	0.00	1203.
NOV	67.6	80.55	35.94	0.00	1873.
DEC	27.6	53.87	49.12	0.00	2254.
YR	76.8	1836.10	511.17	0.00	14279.
TYPE IN CODE NUMBER AND NEW VALUE					

Figure 22. Motor Pool Shop Vent and Floor Load (4000 FT²)

ECONOMIC CONSIDERATIONS

A brief look at the costs associated with the installation of a solar energy heating system was performed. A general design was formulated for the purpose of identifying the significant cost items. This system utilized a liquid flatplate collector array installed on the south facing side of a ground mounted A-frame structure. The A-frame structure was enclosed for structural reasons and to provide storage space for the liquid storage tanks beneath the array. The interface with the conventional HVAC system was assumed to be in the make-up air and supply duct of the main building vent fan (HV3). A liquid-to-air heat exchanger was located upstream of the present boiler-fed heat exchanger for pre-heating the makeup and supply air for the building. This configuration required a collector pump, a heat exchanger pump, the controllers for each, and the associated piping.

The heat transfer and storage fluid was assumed to be a 60/40 solution of ethylene glycol. The cost of the pumps, controls, piping, heat exchangers and their installation were estimated and considered separately from the collector/storage subsystem. A summary of these costs are:

Collector + installation	\$20.00/Ft ² _C
A-frame structure	7.60/FT ² _C
Storage and transfer fluid	4.70/FT ² _C
	<hr/>
	\$32.30/FT ² _C
Other Costs	\$25,000
- Pumps	
- Piping	
- Heat Exchanger	
- Controls	
- Installation	

Using the above data, the cost of a system with 4,000 square feet of collector area was estimated as:

Collector/storage	(32.30 x 4000) =	129,200
Other	=	<u>25,000</u>
Total		\$154,200

A savings can be obtained for larger arrays on the relative cost per square foot of collector for the A-frame structure and storage. An array of 8000 FT_c^2 was estimated as:

Collector/storage	(32.30 x 8000) =	258,400
	Less	= (20,000)
Other	=	<u>25,000</u>
		\$263,400

The thermal analysis for a 4000 and 8000 square foot array is presented in Figure 13 and 10. The annual savings are 735 MBTU/year (8K gallons of oil) and 1,223 MBTU/year (13K gallons of oil) respectively. When the cost of each system was examined over a twenty year period, the 4000 square foot array has a slight advantage. Table 3 presents the fuel cost savings and system cost data over a twenty year period. An initial cost of \$0.50 per gallon of oil was assumed and a ten percent per year fuel inflation rate was used. The system cost data is derived by dividing the total system cost by twenty years and adding an annual maintenance cost.

A more detail cost analysis is required to select an optimal array size and to produce accurate economic conditions. Because other factors can change these results and cause an economic loss, these calculated results should be used with this consideration in mind prior to more accurate calculations.

Table 3 . Economic Data

Year	4000 FT^2		8000 FT^2	
	Saved Fuel Cost	System Cost & Maintenance	Saved Fuel Cost	System Cost & Maintenance
1	4,000	8,210	6,500	13,670
2	4,000	8,240	7,150	13,700
3	4,840	8,272	7,865	13,732
4	5,324	8,306	8,652	13,766
5	5,856	8,341	9,517	13,801
6	6,442	8,379	10,468	13,839
7	7,086	8,419	11,515	13,879
8	7,795	8,402	12,667	13,922
9	8,574	8,507	13,933	13,967
10	9,432	8,555	15,327	14,015
11	10,375	8,605	16,859	14,065
12	11,412	8,659	18,545	14,119
13	12,554	8,716	20,400	14,176
14	13,809	8,776	22,440	14,236
15	15,190	8,840	24,684	14,300
16	16,708	8,908	27,152	14,368
17	18,380	8,980	29,867	14,440
18	20,218	9,056	32,854	14,516
19	22,240	9,137	36,139	14,683
20	24,463	9,223	39,753	14,683
Total	<u>229,098</u>	<u>172,591</u>	<u>372,287</u>	<u>281,791</u>

SOLAR AND CONVENTIONAL HEATING SYSTEM INTERFACE

A study of the conventional heating system was made in order to understand its equipment's interface and operating modes and to determine where solar energy could be interfaced with that system. An explanation of the operation of the conventional system is followed by a discussion of possible solar-to-conventional system interface concepts.

Conventional System Description

The conventional heating system for the Fairbanks Federal Building consist of two major subsystems, a boiler subsystem and a heat recovery subsystem.

Boiler Subsystem

The boiler subsystem consists of a modular boiler, heat transfer medium and units to transfer the heat from the medium to the heated space.

The boiler subsystem uses a 60 percent ethylene glycol - 40 percent water solution to transfer the heat from the boiler to the heating units. The solution temperature leaving the boiler is reset from 200°F to 105°F as outdoor temperature varies from minus 50°F to plus 65°F. The boilers are shutdown when the outdoor temperature is above 65°F. The heat from the solution is transferred into the heated space by unit heaters, fin tube radiators, convectors, air make-up/ventilating units, and through floor coils in the motor pool shop.

The unit heaters have constant heating solution flow through their coils with the thermostats cycling the unit fans to maintain the selected set-point temperature.

The heating solution flow, through the fin tube radiators and convectors, is controlled by thermostat driven modulating valves to maintain setpoint temperature.

Three-way modulating valves in the heating solution lines of the air make-up/ventilating units are modulated to maintain a predetermined day and night duct temperature.

The shop floor coils have constant heating solution flow with the solution temperature being reset from 105° to 78°F as outdoor temperature varies from minus 60°F to plus 65°F.

Heat Recovery Subsystem

The heat recovery subsystem consists of approximately 100 small heat pumps placed along the perimeter of the upper three floors, one air conditioning unit for each of the floors and a water system to transfer and store heat.

The water temperature is maintained between 60°F and 90°F by accepting heat from the boiler subsystem through heat exchange as the recovery supply temperature drops below 60°F, or by rejecting heat to the domestic and city water supply as temperatures rise above 75°F. Heat will also be added through heat exchange from the emergency generator if loop temperature is below 90°F.

Under normal conditions the heat recovery subsystem will operate during the day and be shut down during the night. The heatpumps will operate under thermostat control to provide heating for a 70°F setpoint, or to provide cooling for a 78°F setpoint. Neither heating nor cooling occur between 72 and 78°F. The air conditioners will be controlled to maintain 82°F return air temperature.

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Solar-Conventional System Interface

During the systems study it was determined that solar energy could be integrated with the conventional system in the following ways:

o Preheat Domestic Hot Water

Although this load is small, energy could be added through heat exchange to a tank down stream of the present domestic water sink/storage and not affect the heat transfer from the heat recovery loop.

o Heat Recovery Loop

With the heat recovery loop being maintained between 60° and 90°, it appears that this is an ideal place to use solar energy. Energy could be added to the system through heat exchange; however, there appear to be some problems. At the time that most solar energy is available the recovery subsystem would probably have excess heat which would be rejected to the city water supply. Available data and study time was insufficient to make the necessary analysis of this interface.

o Main Building Make-Up Air

Heat from the solar energy system could be added through a fin coil upstream from the existing coil in HV-3. This would allow the makeup air to be pre-heated, therefore reducing the load on the boiler. The leaving air temperature of the added coil could be controlled in the same way as in the existing system.

o Motor Pool Shop Make-Up Air

Energy could be added here in the same manner as in the main building make-up air.

- o Motor Pool Shop Floor Coils

These coils operate in a good temperature range for utilization of solar energy. Solar energy can service these coils, and heat can be added to the loop through heat exchange from the boiler when solar is insufficient.

- o Shop Unit Heaters

Solar energy may be used to service these heaters with heat added through heat exchange from the boiler when solar is insufficient.

- o Main Building Boiler Loop

The time of year when temperatures are moderate and the boiler loop is setback toward 105°F is also the time when more solar energy is available such that the temperature necessary to service the load is attainable from the solar collectors. A more complete study is needed to determine best interface method and control.

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SOLAR SYSTEM INSTALLATION

Because of its size and the necessity to orient it for maximum exposure to available insolation, the installation of the collector array has the biggest impact on the Fairbanks site. Consideration must be given, however, to installation space for storage tanks, pumps, associated equipment and piping.

Collector Installation

Four possible locations for the collector array were studied and then rejected. Consideration was given to exposure to available insolation, support for the array, possible building modifications, and desirability of locating the storage tanks in close proximity. The rejected alternatives are discussed below.

o Main Building Roof

This is the ideal location for most array installations, but it is not recommended for this application because:

- o building structural modifications would be extensive and impact the construction schedule
- o effective utilization of roof area could not be made due to shadowing effects
- o lack of nearby space for storage tanks.

o Parking Area

- Although this area would require minimum modifications, shadowing from the office structures in the morning hours would decrease system performance.

o Main Building South Face

- This alternative was rejected because of need for extensive structural modifications, preclusion of required tilt angle (see section on Solar Energy System Design and Performance Factors) and lack of sufficient installation area.

o Motor Pool Building Roof

- Need for structural modifications and lack of sufficient installation area eliminated this alternative.

Based upon the above analysis, it is recommended that the collectors be mounted on a surface constructed array frame. Although this is not the ideal location, it does provide the best tradeoff result when evaluated against the cost of building modifications, reduced performance of the solar system and possible impact on the building construction schedule.

It is proposed that the array be constructed in the gravel storage area on the south side of the site between the main building and the Motor Pool Building. This location provides an area of approximately 200' x 30' without impacting the paved area. Locating the collector mounting in this area will also provide the option of contracting for the installation independent of the building construction program.

System Installation

The recommended array location calls for the construction of an "A" frame structure mounted on concrete footings. The interior of the structure would be used to house the storage tanks, pumps and associated piping. The size and structural design will depend upon the number of collectors to be installed, availability of materials and the amount of space within the recommended area that can be allocated to the solar installation.

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